Codes and Standards Enhancement Initiative
For PY2004: Title 20 Standards Development

Analysis of Standards Options for Residential Exhaust Fans

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1. Introduction

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for residential exhaust fans.

2. Product Description

The residential exhaust fan category includes permanently installed bathroom, kitchen, and utility room ceiling and wall-mounted exhaust fans typically moving 50 to 200 cfm of air. Some models also integrate lights and electric heaters. The intended purpose for the fans is to remove objectionable air from the inside of the home to outdoors. Increasingly, these fans are also being used to provide continuous ventilation for maintaining indoor air quality. Excluded from this category are household fans used for cooling, air circulation, radon gas ventilation, heat/energy recovery ventilation, whole-house fans, multi-port fans, and powered attic ventilators.

Figure 1: Bathroom Exhaust Fan.

Source: Broan

3. Market Status

3.1. Market Penetration and Sales

Exhaust fans are ubiquitous in new residential construction, with at least one kitchen range hood and one bath fan installed in each new home. Penetration in existing stock is more difficult to estimate however, with little or no data available that breaks out exhaust fans from general fan categories. Residential surveys conducted by the Energy

Information Administration and many utilities have tended to focus on fans that are used for space conditioning such as whole house fans, attic ventilators, and ceiling fans. Market research conducted for the EPA Energy Star program by Lawrence Berkeley National Laboratory (LBNL) and The Cadmus Group provided data for shipments and stocks, but had definitional problems that made it difficult to use for analysis of exhaust fans only. LBNL estimated that the year 2000 sales of ventilation fans totaled 7 million and range hood fans totaled 3 million. It is not clear what fans are included in the ventilation fan estimate, but it is doubtful that range hood fans are included, as many more bathroom fans should be sold than range hood fans. Therefore, we assumed that the ventilation fan sales estimate was for bathroom fans only. Estimates of stock were developed by first subtracting an estimate of new construction sales, and then using fan life times[1] to estimate current national stock from replacement sales. California estimates of sales and stocks are based on prorating by population and are therefore assumed to be 11% of national estimates (U.S. Census 2000). Sales and stock estimates are summarized in Table 1.

Table 1: Estimated Sales and Stock of Exhaust Fans (1,000's)

	National				*California*	
		Sales				
Type	*Total*	*New*	*Replacement*	*Stock*	*Sales*	*Stock*
Bath	7,000	1,500	5,500	66,000	770	7,260
Range Hood	3,000	1,000	2,000	28,000	330	3,080
Total	10,000	2,500	7,500	94,000	1,100	10,340

3.2. Market Penetration of High Efficiency Options

Several major manufacturers including Panasonic, Greenheck, and Air-King, provide fans meeting Energy Star requirements. As of March 2003 the EPA listed 35 qualifying fans with 17 fans delivering less than or equal to 75 cfm and 18 fans delivering greater than 75 cfm. Average fan efficacies (expressed in cubic feet per minute per Watt) of all the Energy Star fans were 2.8 cfm/Watt and 3.8 cfm/Watt respectively. EPA estimates that currently 10% of ventilation fans are energy efficient.

The recently approved ASHRAE Standard 62.2 "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings" defines minimum ventilation airflow requirements for residential buildings. The standard impacts new buildings, additions to existing buildings, and also some existing buildings. Among the pertinent requirements:

- Continuous whole-house mechanical ventilation at rates varying with building floor area and occupancy.
- Local mechanical exhaust ventilation in bathrooms, kitchens, and rooms with unvented combustion equipment.
- Minimum specifications for fan airflow and noise.

ASHRAE 62.2 does not specify energy efficiency characteristics for ventilation equipment. However, it does specify maximum allowable sound levels, and requires product performance certification for ventilation equipment. Since quieter fans correlate

[1] 12 years for bath fans and 14 years for range hood fans.

well with better fan efficiency, ASHRAE 62.2 may indirectly specify improved energy efficiency characteristics for ventilation equipment.

4. Savings Potential

4.1. Baseline Energy Use

Energy usage for residential ventilation fans is highly dependent on the number of annual operating hours. Since most exhaust fans are operated on an intermittent basis to provide short-term ventilation to a space, Lawrence Berkeley National Laboratory (LBNL) has estimated annual operating hours at 350 hours for bath and utility fans and 200 hours for kitchen range hood fans (LBNL 2002). There is, however, a growing trend in the continuous use of bathroom and utility fans for providing outdoor air ventilation as a means for improving indoor air quality.

The Home Ventilating Institute (HVI), a division of the Air Movement and Control Association International (AMCA) tests and certifies ventilation fans and publishes a directory of HVI 2100 certified fans. Although the HVI directory lists certified product performance levels for air movement (cfm), sound (sones), and power (Watts), power values are published in the directory only at the manufacturer's option. Since only about 15% of the certified products listed in the directory provide power data, the HVI directory is of limited value for comparing energy efficiency of available products.

EPA data representing 126 fans certified under the HVI 2100 program were analyzed in this study (EPA 2002). This data set represents the higher-volume products from the six companies that manufacture 95% of the ventilation products in North America[2]. We will refer to this as the EPA data set. A significant shortcoming of the EPA data set is that it does not include any sales weighting. Because sales of the cheaper and less efficacious fans will be significantly higher, the data set overestimates the average efficacy of current exhaust fan sales. As shown in Figure 2, bath fans included in the EPA data set indicated no significant correlation between fan airflow (cfm) and power (Watts).

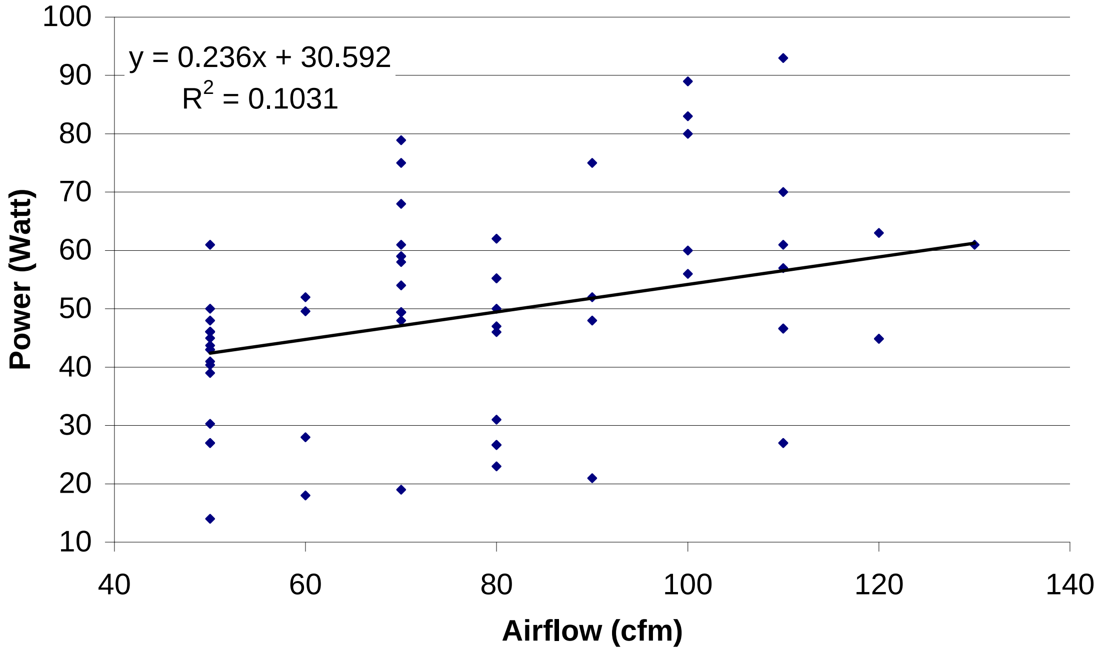
In order to estimate the annual energy use of exhaust fans it is useful to further characterize bath fans by air flow capacity and duty cycle. LBNL estimated the national distribution of bath fans shown in Table 2. We feel that California distributions should be similar for air flow but may be lower for continuous duty fans, but no regional data exists.

Table 2: Breakdown of Bath Fans by Operation and Capacity

Air Flow (cfm)	*Duty*	*Percentage of Total Bath Fans*
<= 75	Intermittent	37%
> 75	Intermittent	59%
<= 75	Continuous	1%
> 75	Continuous	3%

[2] Manufacturer and model number information was removed from the data in order to maintain confidentiality.

Figure 2: Bath Fan Power as a Function of Rated Airflow



Annual unit energy consumption reported in Table 3 is based on current California stock estimates and the average air flow and efficacy values of the EPA data set for each fan category.

Table 3: California Baseline Residential Exhaust Fan Energy Use and Demand

Fan Type	*Duty (Hrs/yr)*	*Air Flow (cfm)*	*Efficacy (cfm/W)*	*End-use Intensity (kWh/yr)*	*Stock (1000's)*	*Annual Energy Consumption (GWh/year)*	*Demand (MW)*
Low CFM Intermittent Bath	350	60	1.44	15	2,712	39	4.5
High CFM Intermittent Bath	350	107	2.26	17	4,309	72	8.2
Low CFM Continuous Bath	8760	60	1.44	363	41	15	1.7
High CFM Continuous Bath	8760	107	2.26	416	198	82	9.4
Total Bath					7,260	208	23.8
Range Hood	200	190	2.59	15	3,080	45	5.2
TOTAL					**10,340**	**253**	**28.9**

4.2. Proposed Test Method

The Home Ventilation Institute standard HVI-916 "Airflow Test Standard - Laboratory Methods of Testing Air Flow Capacity of Residential Ventilation Equipment for Rating" establishes uniform methods for testing residential ventilating equipment. Section 7 of

ASHRAE Standard 62.2P references HVI certification procedures as being representative of procedures acceptable for compliance.

Efficacy shall be calculated by using the airflow and fan motor electrical power values determined by HVI Standard 916 and listed in the HVI product directory. Only fan motor power shall be measured; power used for lights, sensors, heaters, timers, or night lights shall not be included. This approach is consistent with methodology used by the EPA Energy Star rating process.

4.3. Efficiency Measures

Several options exist for improving the efficacy of small residential ventilation fans. Primary options include more efficient motors, a wider blower wheel allowing the fan to deliver comparable airflow at a lower RPM, dual inlet blower wheels, and inlet/exhaust ports designed for minimal pressure drop.

4.4. Standards options

Data on fan efficacy and airflow were plotted to compare similar sized fans in the EPA data set. Figures 3 and 4 demonstrate that efficacy varies greatly within similar airflow groupings for all fan categories. Highest efficacy values often differ from lowest efficacy values by a factor of 3 or 4.

Since limited power data is available in the October 2002 HVI directory, a statistical relationship was developed from the EPA data set to estimate fan power for the full HVI data set. The EPA data set indicated a 61% R^2 correlation between sound (sone) and efficacy (cfm/Watt) for bath fans and a 91% R^2 correlation between airflow (cfm) and power (watts) for range hood fans.

Three different efficacy level options were analyzed for low and high air flow fans. Potential standards levels and the fraction of the EPA data set that meets the standard are summarized in Table 4.

Table 4: Standards Options for Exhaust Fans

Air Flow (cfm)	*Minimum Efficacy (cfm/Watt)*	*Fraction Meeting Level*
<=75	1.2	54%
	1.4	38%
	1.6	18%
>75	1.5	77%
	2	46%
	2.8	26%

Figure 3: Bath Fan Efficacy (<=75 cfm)

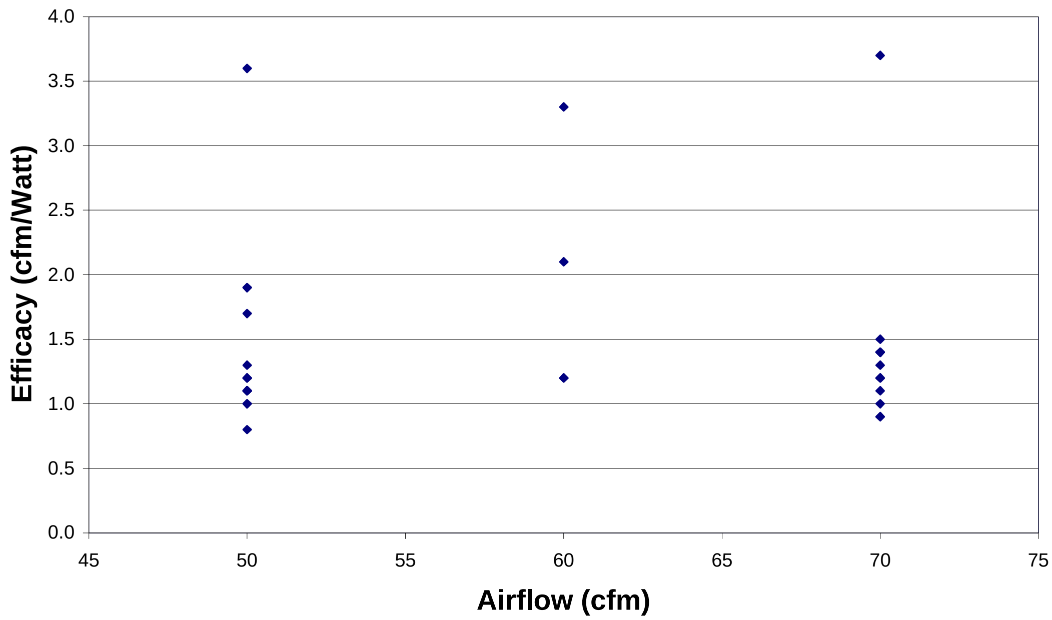
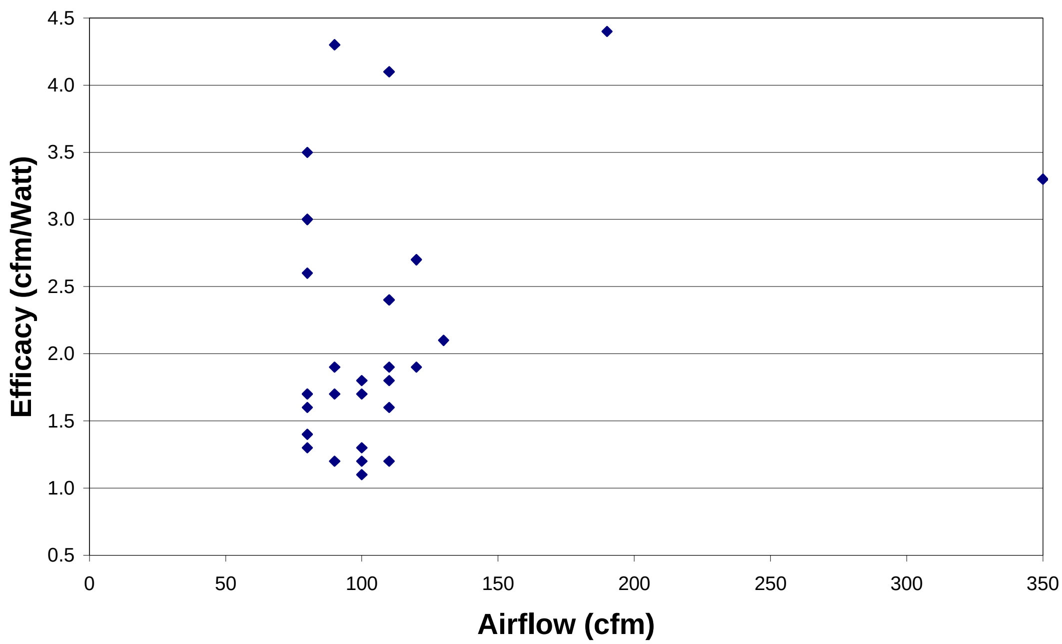


Figure 4: Bath Fan Efficacy (> 75 cfm)



4.5. Energy savings

To estimate energy impacts, the proposed standards were applied to the EPA dataset and the resulting savings were calculated. The percent savings tabulated in Table 5 were applied to California baseline energy to determine the statewide impacts shown in Table 6. The Table 5 energy savings assume no change in the existing fan stock. However, to the extent that ASHRAE 62.2 is referenced by California building standards, fan stocks and energy consumption due to ventilation fan operation will increase, further increasing the statewide impacts shown in Table 5.

Table 5: Projected Energy Savings Due to Standard

Duty	*Air Flow (cfm)*	*Standard Level (cfm/Watt)*	*Per Unit Annual Savings (kWh)*	*Statewide Energy Savings (MWh/year)*	*Statewide Demand Savings (MW)*
Intermittent	<=75	1.2	0.6	1,543	0.2
		1.4	1.6	4,269	0.5
		1.6	2.7	7,418	0.8
	>75	1.5	0.4	1,633	0.2
		2.0	1.6	6,967	0.8
		2.8	4.1	17,792	2.0
Continuous	<=75	1.2	14.2	584	0.1
		1.4	39.4	1,615	0.2
		1.6	68.5	2,807	0.3
	>75	1.5	9.5	1,880	0.2
		2.0	40.5	8,019	0.9
		2.8	103.3	20,478	2.3

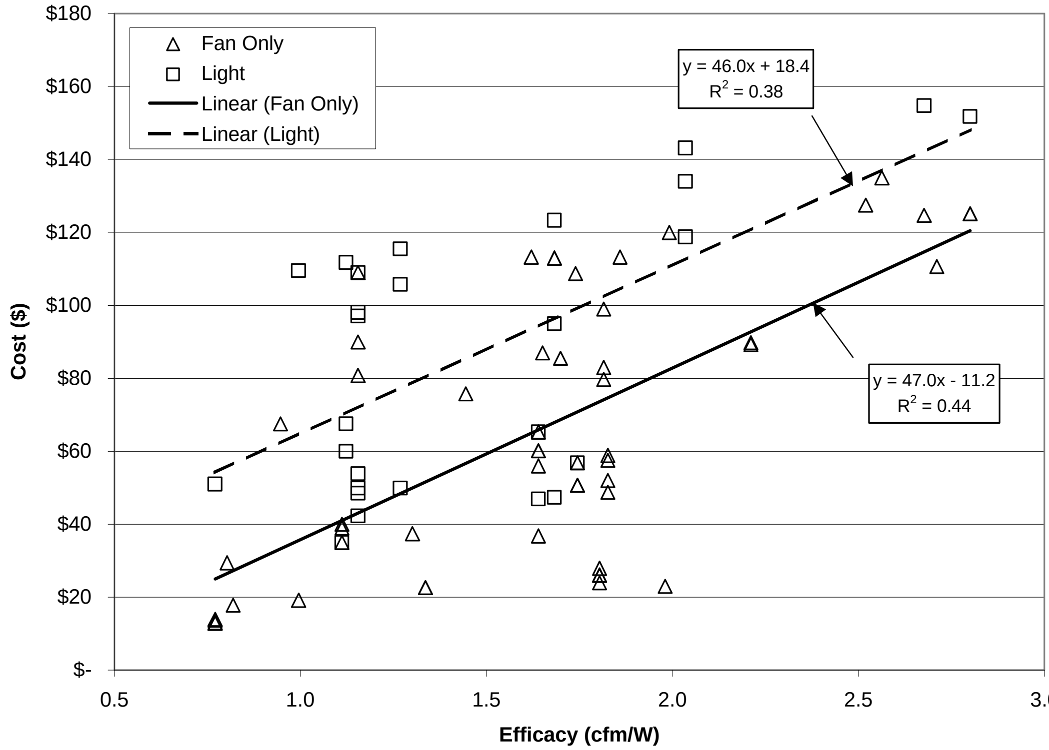
5. Economic Analysis

5.1. Incremental Cost

Pricing for a sample of 113 fans[3] was acquired from vendors representing Air King, Broan, Marley, and Grainger brands. Figure 5 plots retail fan cost as a function of fan efficacy (in cfm/Watt) for fans with and without lights. Although the correlations are low (indicating that factors other than fan efficacy contribute to fan cost), it is encouraging to note that the slopes of the two lines are within 2% of each other (indicating that fan efficacy has a similar effect on the cost of fans with and without lights). Based on these relationships we assumed an added cost of $47 per cfm/Watt improvement in fan efficacy. We did not research the incremental costs of individual fan components or fabrication processes used in the manufacture of higher efficacy fans.

[3] From the 113 listings in the dataset, 26 were Range Hood Fans, 41 were ventilation fans rated greater than 75 cfm, and 46 were ventilation fans rated less than 75 cfm. Fans with heaters, motion detectors, or other added features were not included in the data analyzed.

Figure 5: Bath Fan Cost as a Function of Efficacy



5.2. Design Life

The average life expectancy for exhaust fans is between 6 and 18 years, averaging 12 years (Appliance 2002).

5.3. Life Cycle Cost

The net customer present value was calculated for high and low air flow categories, intermittent and constant flow duty cycles, and the three proposed standard levels. Table 6 summarizes the results and shows that no standard level is economically justifiable for intermittent duty cycle fans. Constant duty cycle fans, however, show a strong positive net customer present value for all flows and standard levels.

Table 6: Analysis of Customer Net Benefit

Duty	*Air Flow (cfm)*	*Standard Level (cfm/Watt)*	*Annual Energy Savings (kWh)*	*Present Value of Energy Savings**	*Incremental Cost*	*Net Customer Present Value***
Intermittent	<=75	1.2	0.6	$0.53	$2.77	-$2
		1.4	1.6	$1.47	$8.25	-$7
		1.6	2.7	$2.55	$15.75	-$13
	>75	1.5	0.4	$0.35	$2.48	-$2
		2.0	1.6	$1.51	$11.47	-$10
		2.8	4.1	$3.84	$35.19	-$31
Continuous	<=75	1.2	14.2	$13.26	$2.77	$10
		1.4	39.4	$36.68	$8.25	$28
		1.6	68.5	$63.74	$15.75	$48
	>75	1.5	9.5	$8.83	$2.48	$6
		2.0	40.5	$37.67	$11.47	$26
		2.8	103.3	$96.21	$35.19	$61

*Present value of energy savings calculated using a Life Cycle Cost of $0.931/kWh (CEC 2001).
**Positive value indicates a reduced total cost of ownership over the life of the appliance

6. Acceptance Issues

6.1. Infrastructure Issues

The options presented for improving the efficacy of small residential ventilation fans include more efficient motors, a wider blower wheel, dual inlet blower wheels, and inlet/exhaust ports designed with minimal pressure drop in mind. These changes involve some redesign.

6.2. Existing Standards

The Home Ventilation Institute standard HVI-916 "Airflow Test Standard - Laboratory Methods of Testing Air Flow Capacity of Residential Ventilation Equipment for Rating" establishes uniform methods for testing residential ventilating equipment. Currently only about 15% of the listed fans report power data.

In June of 2001 the Environmental Protection Agency (EPA) Energy Star program specified sound and energy efficiency criteria for residential ventilating fans to qualify for the Energy Star label. Energy Star fan efficacy is characterized as “cfm of airflow per Watt”. Energy Star criteria are presented in Table 7.

Table 7: Energy Star Criteria for Residential Ventilating Fans

Application and Airflow (cfm)	Minimum Efficacy (cfm/Watt)
Range Hoods (<= 500 cfm)	2.8
Bathroom and Utility Room Fans (<= 75 cfm)	1.4
Bathroom and Utility Room Fans (>75 cfm)	2.8

7. Recommendations

Given the low typical energy consumption of intermittently operated exhaust fans and range hoods, there is insufficient justification in proposing a standard for intermittently operated fans. On the other hand, fans operated continuously or operated to meet an indoor air quality requirement of Title-24 or ASHRAE 62.2 are projected to consume 20-30 times more energy annually than intermittently operated fans and consequently show a very positive net present value. At these higher energy use levels, a standard can be justified but implementation using Title 20 is problematic as fans are not sold for a specific duty.

Even if ASHRAE 62.2 is adopted by state building codes, the majority of vent fans will still be operated intermittently. We therefore recommend the testing and listing of all residential vent fan products according to Home Ventilation Institute standard HVI-916, but do not recommend setting an efficacy standard level at this time. Title-24 can then be used to require that all fans installed for continuous ventilation meet a minimum efficacy level.

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